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A GENERAL METHOD FOR PERIODIC CURRENTS.

BY JOHN MILLS,

Western Electric Co., New York City.

The study of alternating-current phenomena in the curriculum of the technical school is usually postponed until the student has acquired some dexterity with the analytical tools furnished by trigonometry and calculus. The graduate of the high school has received no training in these subjects, which are the bases of our present-day electrical light and power industries, and of our present electrical methods of communication, whether wire or wireless, telephonic or telegraphic. The purpose of this paper is not to advocate an extension of the subject matter of the high-school course in physics. The writer wishes rather to show that the physics and algebra of the high-school course furnish a sufficient basis, without further formal training in mathematics, for the solution of what are usually considered difficult problems of alternating currents.

By the phrase "further formal training" he means calculus and trigonometry as presented in the current mathematical text-books. In one sense the method which will be described involves both trigonometry and calculus; in fact, it also involves some differential equations. But let us forget the formal classification and consider the method. The method, as the reader will quickly recognize, is not original with the writer, although the consistent presentation of the essential portions of the method in an elementary form is probably original pedagogy.*

Assume a soldier facing in any direction and let him be operated upon by the command "About Face." He turns 180°

* A complete presentation of this method as made to a class is given in the writer's recent book "Radio-Communication."

to the left. To an aviator above him the operation appears as a rotation of the line of direction of the soldier through 180° counterclockwise. The command "About Face" is then an operator reversing the direction in which the soldier is facing. A reversal in mathematics is indicated by a negative sign. If, then, our soldier has rotated on his left heel, the position of his left toe* instead of being "1 foot," as originally, is —("1 foot"), that is —1(1 foot). In other words, we indicate the result of the operation of rotating a unit length of line through 180° counterclockwise by the symbol (—1). If we operate again by (—1), that is by "About Face," we obtain the original foot direction. We indicate this operation by —1(—1), which is of course 1. We may say that this checks or we might define the operator by saying that it is of such a character that when applied twice in succession it restores the original state of affairs.

Now, in military terminology we have another operator, namely "Left Face," which is defined by the fact that when applied twice in succession it is equivalent to the operator "About Face." Let us therefore adopt a similar operator, and since the one we already have is used as a prefix or coefficient, we shall use a coefficient in this second case. Thus "i," meaning "Left Face" is an operator rotating the direction foot through 90° counterclockwise. Thus $i1$ is 90° counterclockwise from 1. If we operate upon $i1$ by i, that is if we write $i(i1)$ or, for convenience, $i^2 1$, where the superior 2 indicates the number of successive times the operator is applied, we have $i^2 1 = -1(1)$. It is absolutely beside the point to say that the laws of exponents lead us to $i = \sqrt{-1}$, if we assume them to apply. This process does not constitute a definition of i, as the student is led to suppose, but a definition of $\sqrt{-1}$; a pure abstraction, for which we have no use in this paper.

If our soldier's direction foot was originally east, we may

* Our hypothetical soldier may be assumed to have a F.P.S. system foot.

symbolize east as $1 \cdot E$, north as iE, west as $iiE = i^2E = -E$ and south as $iiiE = i^3E = -iE$. Now, as any boy of high-school age may recognize, you can express any direction by telling how far one must go to the east (or west) and how far north (or south), in order to arrive at a point on the desired line of direction. In other words, any direction can be expressed by telling two distances at right angles to each other. Thus a general expression for a direction to a point and also of the line to it from the origin (from the location of the soldier, if you prefer) is $\pm M \pm iN$ where M and N are distances. For example a distance of X, east, is found by putting $M = X$, and $N = 0$.

Hence in Fig. 1 if OC is the reference direction, any other

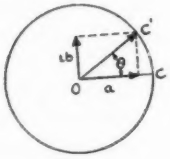

FIG. 1.

FIG. 2.

direction, as OC', is $a + ib$. We may, of course, think of this line OC', as expressed above, that is, in terms of a distance a along the reference axis and a distance b, laid out along this direction and then rotated by the operator "i" as indicated in Fig. 2. On the other hand, as we remember our soldier, we may think of the line OC' as being the result of operating upon OC of Fig. 1, to rotate it through the angle COC', which we shall call θ. We wish, then, to prefix to OC some symbol representing an operator (that is the operation and its result) which will turn OC' through θ counterclockwise. Let us use $\epsilon^{i\theta}$ and write $\epsilon^{i\theta}(OC) = OC'$. Or if OC is of length c then $OC' = \epsilon^{i\theta} c$.

But we have just seen that OC' is $a + ib$. This newly chosen operator must be consistent with this previous result. Hence

$$\epsilon^{i\theta} c = a + ib. \qquad (1)$$

If the line OC is made $1/c$ times as long then the lengths a and b must also be $1/c$ times as large. Or in symbols

$$\epsilon^{i\theta}\left(\frac{1}{c}\cdot c\right)=\frac{1}{c}\cdot a+\frac{1}{c}ib$$

or

$$\epsilon^{i\theta}=\frac{a}{c}+i\frac{b}{c}, \tag{2}$$

Of this relation we shall make use in a moment.

Returning to Fig. 1 let us consider the line OC to be a particular spoke in a wheel which revolves about an axis through O. Assume the wheel to revolve uniformly making f revolutions per second and thus having an angular velocity of $2\pi f$ radians per second. For convenience write $\omega=2\pi f$. If, then, we start the second hand of our watch when the selected spoke passes the position OC, its later position will be given by the angle θ where $\theta=\omega t$ and t is given by the watch.

The continuous rotation of the spoke is then expressed by substituting ωt for θ in ϵ^i and remembering that t, the time, increases steadily. What shall we now substitute on the right-hand side of the equation? It is evident that a and b of Fig. 1 vary as ωt increases. Let us first get a picture of the variations in b by attaching a light to the rim end of our spoke and allowing this light to illuminate a horizontally moving photographic film placed behind the vertical slit S of Fig. 3. [Of course we may obtain a picture of the same result by projecting OC' vertically after the manner of the mechanical draftsman.] The trace which we obtain is a wavy or sinuous line. We call this trace sinusoidal. Physically and pedagogically there seems to be much justification for approaching trigonometry in this way. It is further to be noted that in this way the student is introduced at once to the general idea of the sine of any angle.

Starting our consideration of the trace when our watch starts it appears that the spot of light moves up to a peak, back to its mid-position, that is, zero position, down to a

trough or minimum and back to zero, during one complete revolution of the spoke. The displacement of the spot of light on the photographic record from its zero position is a sinusoidal displacement and depends upon the angular posi-

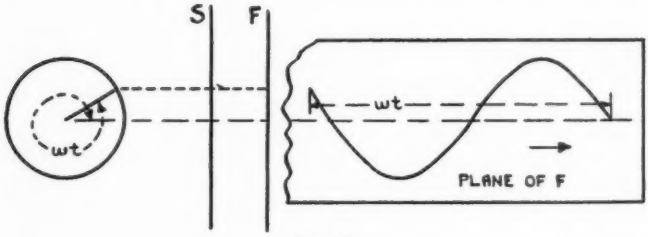

FIG. 3.

tion of the spoke. [If the radius of the spoke is increased the successive displacements are proportionally increased. If we know the displacements for a circle of unit radius we may find them for any other size of circle by simple proportion. Now in equation (1), b represents the displacement of the spot of light corresponding to the angular position, θ, for a circle of radius c. But in equation (2) we have b/c representing the displacement for a unit circle.] Let us call the sinusoidal displacement for a unit circle the sine of the angle ωt and abbreviate it to sin ωt. Hence we may now write for b/c the expression sin ωt.

How about a/c? If our vertical slit S of Fig. 3 is moved around O as an axis for 1/4 turn it is in a position to record the variations in a/c. These displacements will also be sinusoidal but evidently will not start at zero time from zero, but from unity. Let us give a distinctive name to this new sinusoidal motion of the spot of light and call the displacement the cosine of the angle or cos ωt. Then we write

$$\epsilon^{i\omega t} = \cos \omega t + i \sin \omega t. \qquad (3)$$

[To define the cosine more accurately note that cos ωt is the same sinusoidal curve as we obtain if we start our watch one

quarter of a period later than we did in obtaining the sine curve; or in other words, cos ωt is the sine curve which would be obtained if the spoke was allowed to rotate a quarter revolution, that is $\pi/2$ radians before we started the watch. Hence

$$\cos\ \omega t = \sin\ \omega(t + T/4) \quad \text{where } T = 1/f$$

and

$$\cos\ \omega t = \sin(\omega t + \pi/2)$$

are definitions for the cosine of an angle.]

In equation (3) we have the expression for a rotating vector in terms of two sinusoidal components which are at right angles to each other. Suppose that the vector is to be rotated clockwise; how shall we represent it? Obviously, if the direction of rotation is reversed we must reverse the sign of "i" giving

$$\epsilon^{-i\omega t} = \cos \omega t - i \sin \omega t. \tag{4}$$

This vector with the reversed direction of rotation we shall call the conjugate of the original vector.

Now note that the sum of two conjugate vectors (as obtained by adding equations (3) and (4) is a sinusoidal function of the time since rotation started. Thus

$$\epsilon^{i\omega t} + \epsilon^{-i\omega t} = 2 \cos \omega t. \tag{5}$$

Remembering that a cosine function represents a sinusoid we see that equation (5) permits us to represent any sinusoidal wave motion, e. g., an electrical oscillation, in terms of a rotating vector and its conjugate. The convenience of this representation will appear shortly. [Note that it is not rigorous to use equation (4) or equation (3) to represent a sinusoid for these equations each represent two different sinusoids, one of which is commonly spoken of as imaginary. Now the simple harmonic motion of an electron in a wire carrying an alternating current is in no sense imaginary, and on this basis alone should not be represented by an expression involving a so-called imaginary.]

Returning to Fig. 1 let us see how to represent a vector which starts at $t=0$ not from the position OC but from some position θ radians in advance, as OC'. The vector OC' is $\epsilon^{i\theta}\,OC$. If this vector, OC', is to be rotated with the velocity ω we merely operate upon it by $\epsilon^{i\omega t}$ giving the desired vector as $\epsilon^{i\omega t}\epsilon^{i\theta}\,(OC) = \epsilon^{i(\omega t+\theta)})\,(OC)$. This vector is always θ radians ahead of $\epsilon^{i\omega t}(OC)$ and is therefore said to lead it in phase by θ. Its conjugate is of course $\epsilon^{-i(\omega t+\theta)}(OC)$.

Now let us consider the electrical problem of finding the effective value of a sinusoidal alternating current of frequency f and maximum value I_m. Let the current be

$$I = \frac{I_m}{2}(\epsilon^{i\omega t} + \epsilon^{-i\omega t}). \tag{6}$$

The effective value is the square root of the average value of the square. [The occasion of this definition in the phenomenon of the heating effect is not considered here for the sake of brevity.] Then the square is

$$I^2 = \frac{I_m^2}{4}(\epsilon^{2i\omega t} + \epsilon^{-2i\omega t} + 2\epsilon^0)$$

or

$$I^2 = \frac{I_m^2}{4}(\epsilon^{i2\omega t} + \epsilon^{-i2\omega t}) + \frac{I_m^2}{2}. \tag{7}$$

What is the square? Obviously, it is a sinusoidal effect of double frequency and an effect of zero frequency. The average of the double frequency sinusoid is zero. The average of the zero frequency effect is of course its steady value, $I_m^2/2$. Hence

$$I(\text{eff.}) = \frac{I_m}{\sqrt{2}}. \tag{8}$$

[The reader may be interested in the simplicity of the proof that the average power is $E(\text{eff.})I(\text{eff.})\cos\theta$. To show this* write both E and I in the general form shown in equa-

* This theorem is thus developed in "Radio-Communication."

tion (6), but give to them a phase difference of θ, multiply, neglect the double frequency sinusoid and remember that $2\cos\theta = \epsilon^{i\theta} + \epsilon^{-i\theta}$ as follows from equation (5).]

A further convenience of the form of expression given in equation (5) appears in the case of alternating current circuits involving inductance and capacity. The self-inductance, L, of a circuit is defined as the ratio of the E.M.F. across its terminals to the "rate of change" of current in it. Thus $E/pI = L$ where the prefix "p" is an operator representing the result of obtaining the rate of change of the quantity to which it is prefixed. [The term "operator" and this entire concept should not be difficult. What is the speedometer of an automobile? It is an operator which we prefix to a car to obtain at any point in the machine's travel (that is for any value of S, the total distance the car has gone) the rate of change of space (that is pS).] The capacity of a circuit may also be expressed in terms of a current, and a rate of change of voltage, but it is sufficient to illustrate the method by using inductance only.

It is then evident if an alternating current of I, where $I = (I_m/2)(\epsilon^{i\omega t} + \epsilon^{-i\omega t})$, flows in an inductance L that the E.M.F. required is LpI. To find pI note that $I_m/2$ does not change and that what we really wish to know is $p(\epsilon^{i\omega t} + \epsilon^{-i\omega t})$, that is, $p\epsilon^{i\omega t}$ and its conjugate. [Simple reasoning will convince one that the operator p is associative. Thus symbolize interest rates on money in terms of p.]

Consider Fig. 4 where are shown $\epsilon^{i\omega t_1}$, and $\epsilon^{i\omega t_2}$. If ωt_2 is

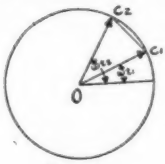

FIG. 4.

not much larger than ωt_1, it appears that the quantity C_1C_2 which must be added to OC_1 (*i. e.*, $\epsilon^{i\omega t_1}$) in order to obtain

OC_2 (*i. e.*, $\epsilon^{i\omega t_2}$) differs but imperceptibly from the arc of the circle. Now the angle $\omega t_2 - \omega t_1$ is measured by this arc, thus

$$\omega t_2 - \omega t_1 = \frac{\text{arc } C_1C_2}{OC_1} = \frac{C_1C_2}{OC_1}.$$

Hence C_1C_2, which is the change in the rotating vector, is $C_1C_2 = OC_1(\omega t_2 - \omega t_1) = \omega(OC_1)(t_2 - t_1)$. The change per second is then

$$\frac{C_1C_2}{t_2 - t_1} = \omega(OC_1)$$

and is of direction C_1C_2, that is perpendicular to the radius OC_1. This perpendicularity is of course to be indicated by prefixing the operator "i" thus $i\omega(OC_1)$. That is

$$p\epsilon^{i\omega t_1} = i\omega(OC_1) = i\omega\epsilon^{i\omega t_1},$$

or in general

$$p\epsilon^{i\omega t} = i\omega\epsilon^{i\omega t},$$

and if

$$I = \frac{I_m}{2}\epsilon^{i\omega t} + \frac{I_m}{2}\epsilon^{-i\omega t}$$

then

$$pI = \frac{i\omega I_m\epsilon^{i\omega t}}{2} + \frac{-i\omega I_m\epsilon^{-i\omega t}}{2}.$$

The E.M.F. E is then $L\omega(I_m/2)(i\epsilon^{i\omega t} - i\epsilon^{-i\omega t})$. This may be put in the more usual form by noting that in equation (3) if $\omega t = \pi/2$ then $\epsilon^{i\pi/2} = i$ since the cosine for a quarter revolution is zero and the sine unity. Similarly from equation (4) $\epsilon^{-i\pi/2} = -i$.

Hence

$$E = \frac{L\omega I_m}{2}(\epsilon^{i(\omega t + \pi/2)} + \epsilon^{-i(\omega t + \pi/2)}).$$

In other words, the E.M.F. required to overcome the self-induction is also a sinusoid but is $L\omega$ (or $2\pi fL$ times as large) and leads the alternating current by 90°. To the reader who

has studied alternating currents this result is of course familiar.

If the currents with which we deal are not sustained but are decaying they may be represented by vectors which, in rotating, trace spirals instead of circles and for which the sinusoids are damped. Such vectors are of the form $\epsilon^{-at}\epsilon^{i\omega t}$. Hence the general expression for an alternating current may be written

$$I = \frac{I_m}{2}(\epsilon^{-at+i\omega t} + \epsilon^{-at-i\omega t}). \tag{10}$$

Now for illustration consider a circuit containing a resistance of R ohms and an inductance of L henries. What is the current in the circuit due to a steady E.M.F. of E volts from a battery? Start our watch at the moment the battery is connected. (At this instant the current is of course zero.) At any instant after starting the E.M.F., E, impressed on the circuit must equal that required to force the current through the resistance plus that required to force it through the inductance. If I represents any instantaneous value of the current then

$$E = RI + LpI. \tag{11}$$

Since the battery will ultimately force a steady direct current through the circuit let us represent I by the sum of two component currents, one the forced current which will ultimately flow, say I_0, and the other a transient current which we will write in general form as $(I_m/2)(\epsilon^{(a+i\omega)t} + \epsilon^{(a-i\omega)t})$. Then

$$I = I_0 + \frac{I_m}{2}(\epsilon^{(a+i\omega)t} + \epsilon^{(a-i\omega)t}) \tag{12}$$

and

$$pI = \frac{I_m}{2}[(a+i\omega)\epsilon^{(a+i\omega)t} + (a-i\omega)\epsilon^{(a-i\omega)t}]. \tag{13}$$

Now when $t=0$, we have $I=0$, hence putting $t=0$ in equa-

tion (12) gives

$$O = I_0 + \frac{I_m}{2}[2] \quad \text{or} \quad I_m = -I_0.$$

But by Ohm's law the ultimate steady forced current will be

$$I_0 = \frac{E}{R}. \tag{14}$$

Hence

$$I_m = -\frac{E}{R}. \tag{15}$$

Also when $t=0$ we have from equation (13)

$$pI = \frac{I_m}{2}[2a]. \tag{16}$$

Now equation (11) holds for every instant and therefore for the instant when t is zero. At this instant $I=0$, and

$$LpI = LaI_m = -\frac{ELa}{R}$$

by equations (15) and (16). Hence substituting these values in equation (11) we have

$$E = R\cdot 0 - \frac{ELa}{R} \quad or \quad a = -\frac{R}{L}. \tag{17}$$

Substituting from (17) and (14) in equations (12) and (13) and then in equation (11) gives

$$E = E + \frac{E}{2R}[iL\omega\epsilon^{(a+i\omega)t} - iL\omega\epsilon^{(a-i\omega)t}]. \tag{18}$$

But equation (18) can only hold if ω is zero; that is from this equation we obtain $\omega=0$. Hence substituting $\omega=0$ and $a=-R/L$ in equation (12) gives

$$I = \frac{E}{R}(1 - \epsilon^{-Rt/L}). \tag{19}$$

[It is not necessary to solve for ω if it is recognized that of the two types of storage reservoirs for energy, namely, inductance and capacity, only one is present in this circuit and hence energy transfers from one type to the other type cannot occur. That is, there can be no alternations in the direction of the current and hence the only current possible is one of zero frequency, that is of zero angular velocity.]

Summary.—The method which has been presented and illustrated by three examples may be summarized as follows: (1) The concept of the vector operator "i"; (2) the concept of a rotating vector and its expression as in equation (3); (3) the rate of change of a rotating vector; (4) the concept of a conjugate vector; (5) the representation of a simple harmonic motion, e. g., an alternating current, by the sum of two conjugate vectors; (6) the representation of a damped alternating current by the sum of two conjugate vectors which are similarly reduced exponentially. With the tools thus obtained, the transients of spark set wireless transmitters, the oscillations of tuned and coupled circuits, the currents in unbalanced three phase circuits, the impedances of transmission lines and other similar magnitudes may be dealt with quantitatively by purely algebraic methods. As a by-product of this method we have a suggestion for a method of approaching trigonometry which might be used with some types of students to shorten the time now required for its study.

A NEW POINT OF VIEW IN LABORATORY WORK.

BY WALTER LYMAN UPSON,

Associate Professor of Electrical Engineering, Union College.

It is not my wish to press too hard the claim of novelty. There are many laboratories with which I am naturally quite unfamiliar. So far as I know, however, the general method, or system, advocated is not at present in force anywhere except partially in the Union College electrical laboratory. I must also acknowledge that my experience is somewhat limited to engineering, and more particularly to electrical engineering laboratories. There need be, however, no such limitation on the application of the system, for it is based on principles applicable to all subjects taught, even to those which do not at present ever make use of the laboratory or of laboratory methods.

The first element in my "point of view" is the laying of emphasis upon *individual creative work*. In this connection I wish to express my satisfaction at finding recently most convincing support of the general idea on which I am working in Professor Henry Fairfield Osborn's little book entitled "Huxley and Education." The idea which he develops is summed up in a word, which I quote, from page 9, namely ". . . the lesson of Huxley's life and the result of my own experience is that *productive thinking* is the chief *means* as well as the chief *end* of education, and that the natural evolution of education will be to develop this kind of thinking earlier and earlier in the life of the student."

The second element is the laying of emphasis on the laboratory as against the class room. I think that generally the laboratory follows, and is in a sense subordinate to the class room. I would emphasize the laboratory at the expense of the class room, even to the point of making it paramount.

The object of this is to secure free play to the laboratory for the theoretical investigation and pursuit of problems developing therein.

As I have been working over the above principles and their application, the whole system of college, and even of secondary, education has become involved in a most fascinating and far-reaching way. When it comes to putting them into practice, however, it is only practicable for me now to do so in a very limited way, beginning with small things, so to speak, in the hope of finding therein justification for their further extension to the larger sphere. Bearing these two principles in mind, then, and especially the first regarding individual creative work, I propose to relate something of what is going on in my laboratory courses at the present time, hoping thereby to give concrete expression to the real meaning of the incorporation of these ideas into the educational process.

A short time ago, a junior came into my office in the laboratory to say that he had obtained very peculiar results in his experimenting of the previous day. We discussed the work for about five minutes, and he went out to make further investigation. His problem related to the change in resistivity of an electrical conductor under variation of tension. Having previously made a few determinations of resistivity, he undertook to build apparatus by which a piece of wire could be gradually stretched while current was passing through it. The apparatus was completed a few days ago, and yesterday, his regular laboratory day, he made his first series of tests. At the present time I have reason to believe that he is really interested in the fundamental law of resistivity and in the electrical properties of conducting materials. He has created something himself, namely the apparatus which he designed and built after suggestions from me. There is still before him the exploitation of his apparatus, and the constructive work of obtaining and assimilating his results. Although the laws involved are simple, this means the correlating of numerous quantities, namely, length, area, nature and quality of the

wires tested and their resistances and resistivities under various degrees of tension and temperature.

This is work which will involve considerable time if properly done. Had the student spent the same time doing four or five routine experiments instead, with the handing in of four or five routine reports, would he have accomplished anything like as much? The fact is, he is spending extra time on this work because he likes it. Is it not reasonable to expect that a year of well-chosen problems of this kind will do much toward making an enthusiastic and intelligent investigator of him? I regret, of course, that the possibilities are limited by the lack of available time in so crowded a course as that of our junior electricals. What I wish to do is to be able to carry forward the theoretical investigation which is opened up and started by such practical problems in the laboratory.

Sometimes it is quite as desirable to have two students work together as to have them separated. In such cases they should be equally self-reliant. Then they can discuss and plan out their work, and they can work faster on constructing apparatus and computing results. I have been grouping men in pairs but have often separated them from time to time, especially where one of a pair had a tendency to lean on the other. Here is an instance of two men working together in harmony. I assigned them an experiment in calibrating direct current voltmeters and ammeters. Besides learning general methods and our particular arrangement of circuits and apparatus for this work, they were to study the principles of action of the meters.

Then I gave them an old meter which happened to be on hand. It had a large scale and was intended for vertical mounting. I thought it could be used to advantage in connection with demonstrations if it were put in working order and properly mounted. Well, they have now been working on that meter for two weeks. It seems as though they had learned all about its internal arrangement, its delicacy of

adjustment, various precautions that must be taken to get results, and in fact they have achieved a degree of competency in handling that class of instrument which ought to remain with them and be readily extended to other work they will do later.

I would not give every member of the class an old meter to work with. In this instance it has made a successful individual problem for each of these two men who have puzzled, studied and labored over it. When finally mounted, calibrated and made to appear as presentable as possible it should be a useful addition to our equipment and a source of some satisfaction to the students who worked upon it. Many similar instances could be given to show the large amount of what must rightfully be acknowledged to be creative work that is being done by these juniors. It must be borne in mind that they are having their first experience in electrical work, except for the small amount of electricity given in their sophomore physics course.

I will give one more instance for the sake of making my story more general. Two students were assigned to study the incandescent lamp, especially with reference to its electrical resistance and temperature coefficient. They started by reading up on the subject of lamp construction and manufacture. The first experiment was with a carbon lamp under variable impressed voltage. To their surprise they found the lamp to have a positive temperature coefficient of resistance instead of negative, as commonly assigned to carbon. On investigation, they found their results to agree with those given for the metallized carbon filament and this was what their lamp proved to be. Then they wanted to try an old type carbon lamp to see if they could get the negative coefficient. Also they tried tungsten, and the enormous change of resistance offered by this metal in going from cold to hot was of lively interest. We also found a tantalum lamp and a carbon lamp which had lost its vacuum. Altogether there was quite a good variety.

The next step was to try to obtain experimental verification of some questions I gave them relating to series-parallel circuits made up of lamps. For instance, one lamp in series with two in parallel—if they are alike and double voltage is impressed, will the lamps operate acceptably? This question was answered theoretically, and many similar questions. For the experiment, they wired up a small board with three lamp sockets. It was unnecessary to apply double voltage and burn out some lamps, for the relative brilliancy was just as acceptable on reduced voltage. They noticed that when a carbon lamp and a tungsten lamp are in series, on closing the switch the former lights up at once while the latter comes up slowly to its final brilliancy. The effect was very pretty and they were interested enough to discover the reason for it themselves, which they were able to do with the help of their experimental data.

But with all this experimenting with lamps they began to feel that they were after all missing the main point by not making tests of illumination. Now it happens that we have no photometer in our laboratory. But, a few years ago I had had two seniors design and construct an illuminometer as thesis work. This apparatus had been very successful. We also had a class room which was inadequately lighted, the result of unfortunate arrangement of the lights rather than an insufficient number of them. So, I gave the boys this problem: they were to measure the illumination of this room with the illuminometer, in the meantime studying up the fundamental principles of illuminating engineering.

Then they were to plan out changes, make them and compare results. They have put in many evenings on this work during the past four weeks. At present the room is very finely illuminated, although the work upon it is not yet quite completed. Anyone may be seated in it at random and be sure of listening to the lecture without subjection to the slightest inconvenience due to the lighting. The blackboard behind the speaker is brightly illuminated, and there is enough

general diffusion about the room to permit of the taking of notes by anyone in the audience. Moreover, under the old arrangement the power consumed was 1000 watts, while now it is but 700 watts, making a saving of 30 per cent., a small item, but one which ought to be appreciated by the college administration.

The next logical step is the photometer. Whether or not it will be best for me to put these two students on the problem of designing and constructing a photometer remains to be decided. Their work ought to be kept properly balanced. At the same time it must be acknowledged that they have learned a great deal besides illumination since they began on the incandescent lamp a month ago. If they really desire to make a photometer, I shall, in all probability, let them do so, and with all my heart, because my whole scheme falls completely to the ground when I fail to regard the student's interest.

But now, with the above incidents in mind, someone may ask: "Do you really attempt to apply this method to all students in the electrical laboratory?" I answer, "assuredly, I do. It is the general laboratory method." Students do not always respond with enthusiasm, it is true. They have been trained for years not to be enthusiastic about their educational work. But I had one, last year, who dropped out shortly before the Christmas holidays. He was a fine fellow, tall, athletic and with a good head on his shoulders. I hear that he is now a United States officer serving his country "somewhere in France." As a student, he was pretty much of a failure, and undoubtedly he was, himself, largely to blame.

But he told me, shortly before leaving college, that his laboratory course was the only work he had had in more than two years of college that had interested him in the slightest degree. To instill interest in such students is by no means an easy task. This is not a reflection on the instructors, for the

very best of them recognize the difficulties inherent in our present system, in this respect.

The work I have described relates to juniors. With seniors it is somewhat different the way I am doing it now. This is because I consider it very important to train the juniors carefully in the way they ought to go, while the seniors, having been already trained, may be trusted to work to a large extent upon their own initiative or at least without a great deal of supervision. I have two seniors assisting me with junior work but no assistance with senior work. In fact, under the pressure of theory and other courses the time available for extensive senior laboratory work is insufficient to permit of very much departure from the usual experiments with electrical machines. Nevertheless, the method certainly does apply also to seniors. Each group of two or three receives its assignment of work individually from me. Always there is the likelihood that something special will develop and give a particular interest to the experiment. My conception is that the theoretical side of the work should grow more and more in importance with the increasing knowledge of the student, and that seniors should naturally spend less time than juniors on the more mechanical side of laboratory work. But I should like to have the theoretical work of seniors as well as juniors emanate largely from the laboratory.

Possibly there is enough food for thought in what has already been written. There are, however, a few more things that should be said and that ought to be borne in mind by anyone who attempts to appraise this system. The ideas are being, at present, very imperfectly carried out for several reasons. One reason is that no readjustment between the laboratory and other work of the course has been made with a view to giving the laboratory a dominating position with respect to the students' theoretical studies. This naturally places a limit on the amount of expansion possible to the laboratory, which is determined mainly by the available free time of the students.

Another reason for limited results is that there has been, as yet, no attempt to give this method proper setting in the electrical course as a whole. Such a setting, it has seemed to me, would call for the admission of students to work in the electrical laboratory in the sophomore year if not earlier. Where a good share of mechanical work is included there is much that could be done by freshmen or sophomores just as well as by juniors. This would lend interest to their work and they could easily be required to maintain a higher standard of accomplishment than now generally exists.

It appears that some rearrangement of the course would be necessary as respects non-engineering subjects. These need by no means be subject to curtailment, but possibly would be advanced somewhat so as to spread along over the whole course instead of being concentrated in the first two years. In the electrical laboratory, juniors would be far more advanced and proficient than at present, and seniors still more so. Stress would then be laid upon creative work all along the line.

I realize that considerable burden would rest upon the laboratory instructors. But then the entire electrical department would be concerned primarily with laboratory work. Right here also is one of the most important features of the whole plan. We should utilize a large number of student assistants. It is well known that a student who is assisting learns a great deal from this work. It would therefore be beneficial to employ quite a large number of seniors to assist with juniors, sophomores and freshmen, and in some instances juniors also might be appointed to assist with the lower classes.

If there are graduate students a few of these would naturally be available to act as assistants with the senior work. The professor's work would then be largely to originate problems and supervise assistants. But he would also keep in contact with all the work going on in the laboratory and confer frequently with individual students, stimulating their interest and coöperating with them in the various stages of the work.

In my present situation it is not possible to give over as much routine work for work of the higher order as I should like, and consequently I can hardly expect to get the maximum of good results. Supervising the laboratory work of about fifty students with the help of two senior assistants naturally keeps us all pretty busy. Nevertheless, I should hate to go back to the old routine list of experiments. The individual problem certainly lends itself to the stirring up of interest as no routine program can ever hope to do. There are a hundred ways of verifying Ohm's Law; why should we limit ourselves to one prescribed way in the laboratory?

This, then, is my new point of view in laboratory work; the professor, an originator of problems, experiments and ideas, a corps of student assistants drawn from the upper classes, guiding, and helping to create an atmosphere of research among those they are assisting, and finally, the individual student working upon his own problem, creating, experimenting, analyzing and generalizing. The laboratory thus leads into the theory, and dominates it. We progress, as heretofore, from the simple to the complex, but in addition to that it is now also from the concrete to the abstract, from the particular to the general. This, it seems to me, lies at the foundation of the question of how we are to educate capable scientific investigators and engineers in America.

TECHNICAL ENGLISH.

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I. *Standards of Scientific and Literary Composition.*—In much discussion of technical writing there is the danger of creating the impression that it is governed by a set of principles peculiar to itself. If there is a boundary between technical and literary composition it is hardly in any essential respect that would entail a special method of teaching. Technical and literary English may be regarded as two different fabrics which are woven in the same loom. The warp and woof of the one does not differ from that of the other; but the fabric may have the sturdy quality and the loose finish of a woolen, the compactness and the gloss of a fine linen, or possibly the composite nature of a linsey-woolsey. The loom is impartial in its contribution. The method is unchanged. The differences in the finished products lie mainly in the quality and nature of the raw material.

But the quality of the student's mind accounts largely for the presence or the absence of a literary flavor in his composition work. Literary virtue is largely a color of the mind which gets itself represented in language, pretty much as humor, or satire, or wit lends a flavor to a piece of writing without affecting the rules of structure which are common to technical and literary composition. Literary expression is sometimes thought to be a matter of aptitude, perhaps even a matter of ancestry. A given subject, or possibly any subject, may be given literary treatment, but only by a writer with a literary turn of mind.

Technical English is more especially applicable to facts and is likely to be more or less formal; literary English is especially applicable to truths and is apt to be more or less imagi-

native. The one most often makes an intellectual, and the other an emotional, appeal. If we ask of Mr. Peele's treatise on the "Compressed Air Plant" and of Mr. Howells's novel called "The Rise of Silas Lapham," Are they true? we shall have to say that they are. The one is true to scientific fact and the other is true to human nature. But when we have read the treatise we are in possession of the facts, and so it has no power to allure us back to it. When we have read the novel we are likely to be so pleased with its emotional appeal as to go back to it again for a renewal of the emotion; and with each re-reading we are likely to discover some new phase of truth with its attendant emotion. The permanency of knowledge renders the treatise of merely ephemeral interest: the transiency of emotion makes of the novel a permanent delight. The novel is to be absorbed and interpreted rather than read and remembered. The power it has to bring one back to it again and again is its title to literary quality. And so Mr. Peele, once read, has delivered his message, except as he may have availed himself of any opportunity to impart to his composition a literary flavor. Mr. Howells, on the contrary, is likely to be of permanent interest.

Technical writing, in other words, seems to be specific rather than general, objective rather than subjective, matter-of-fact rather than imaginative. It bases its worth on the information it gives, provided the information be copious and accurate and so orderly in its presentation as to be readily understood. It concerns itself with that about which definite statements are to be made and provides a minimum of opportunity for imagery, for word-painting, or for the play of the fancy. It makes use mainly of a terminology that carries a prescribed and well-understood meaning, and does not commonly employ a word that has associations apart from its accepted definition and use. It carries a minimum of implication, or of matter to be read between the lines, or interpreted by the reader depending upon his imaginative and emotional nature. In

other respects the technical writer is on a common ground with the literary artist.

But so unencumbered with any literary intent is the average student of technical composition that he is entirely willing to waive his right to be interesting in favor of the interest that is naturally inherent in the subject matter. His facts are too little likely to be enlivened by his sympathies, brightened and vivified by his imagination, or made picturesque by skilful use of language. He causes the instructor no apprehension in the direction of literary dash, but lays upon him the task of imparting a respect for a well-chosen word, a well-groomed sentence, and a well-built paragraph. He seems to nurse an aversion to a legitimate use of pronouns, participles, particles, and parallel construction. Yet, in his observance of the points covered by this alliterative group of terms is his chief hope of acquiring an adequate style of writing.

II. *Standards of Structure.*—Although any given flaw in language may of itself seem unimportant, yet, like a loose joint or a maladjustment in a machine, it is certain in some degree to hinder its efficiency. Niceness of adjustment and smoothness of movement are the last and subtlest indications of power and efficiency in language. Mere authority for the use of a given form of expression weighs light beside the necessity that the language deliver its freight of thought with certainty and without depreciation. The language must not be liable for damages inflicted upon the thought in transit. Facility with the vehicle of thought comes, aside from a matter of aptitude, from an acquaintance with a few devices of manipulation. To ride a bicycle or to shade a drawing baffles one till he learns the trick. It is even so with the smooth and certain conveying of a thought, which is conditioned largely upon the correct use of *parallelism, verbals, reference,* and *connectives.* These are the fundamental points, and they need only to be examined with some degree of respect to yield up their secrets. They are a common source of uncertainty to

the writer who has not taken the pains to examine them in detail.

Parallelism.

To get a clear view of parallelism in language, let us first look at the Panama Exposition. The sameness in architectural design was the means of putting the buildings into one family, and the uniform smoked ivory effect in the color scheme completed the blending of the composite city into a unit. Or again, look at the farmstead in which all the buildings are of the same material and painted the same color. Look at the regiment in uniform or the choir in costume. Uniformity on the part of the coördinate members emphasizes the unity of the group. To give unity to a structure, whether it be called a house, a human character, or an English sentence, there must be consistency, or uniformity, especially with regard to the treatment and the aspect of the like parts.

Uniformity is a cloak that covers a multitude of errors. The statement might well be a proverb, so widely extended is its application. It is applicable to the organization of an army, or to an allied attack upon an enemy. It is applicable to the building of railway cars or of road-wagons, to the manufacture of plows or of window-sash, or to the laying of a conduit-pipe. It is as true of a sentence as of a gas-main that the parts which are similar in purpose must be similar in form, to enable the commodity to be delivered to flow unencumbered and without leak. The following sentence, for instance, violates the principle of uniformity in the similar or coördinate parts and so encumbers the flow of the thought: "The first Watson life-boat had low end-boxes, not for righting purposes, but in order to decrease the space that could be filled by shipping a sea." The supposed reason and the real reason for the low end-boxes are the two similar or coördinate parts of the thought, and they should be expressed in similar language. But in the sentence, as written, the one is expressed with the prepositional phrase *for righting purposes* and the other with the infinitive *to decrease*. It is as though the right

wing of the Capitol were built of red granite and the left wing of buff brick. Express both the reasons for the low end-boxes in the same form of language and note the swiftness with which the sentence delivers its thought: The first Watson life-boat had low end-boxes, not *for righting purposes,* but *for decreasing the space that* could be filled by shipping a sea.

The "and which" and "but which" error arises from the neglect of this same principle of parallelism: "There are some other rays given off in a similar way, along with the Röntgen rays, *but which* are not Röntgen rays." The coördinate conjunction *but,* or *and,* or any other coördinating conjunction, joins elements of thought which are coördinate and which consequently require similar language. As the conjunction *but* in the sentence is followed by a relative clause we naturally look to see it preceded by a relative clause. Vice versa, as it is preceded by a participial phrase we naturally look to see it followed by a participial phrase. In other words, the participial phrase *given off in a similar way* is balanced over against the relative clause *which are not Röntgen rays.* Note the good effect of making the conjunction to balance two relative clauses: There are some other rays *which are given off* in a similar way, along with the Röntgen rays, but *which are not Röntgen rays.* Or two participial phrases: There are some other rays *given off* in a similar way, along with the Röntgen rays, but *not recognized as Röntgen rays.*

In the following sentence one of the two coördinate ideas is expressed in a participial phrase and the other in an independent statement: "We found other bones and teeth, *some* evidently *belonging to a stout and heavy animal,* the *others suggested* an animal of lighter build." *Some* and *others* are the bases of the two coördinate ideas, and for effectiveness one should express what he has to say about *some* and *others,* respectively, in parallel statements: We found other bones and teeth; *some* evidently *belonging* to a stout and heavy animal, and *others suggesting* an animal of lighter build.

VERBALS.

The term *verbal* is merely a general name for some three or four forms of speech, which either name or express the action, but which do not predicate anything of a subject. Having no office, therefore, as finite verbs, they are sometimes called infinitives. But as one of the four forms is commonly known as an infinitive, the term verbal obviates the danger of confusing the genus with one of the species. The four forms are, the *gerund*, the *participle*, the *verbal noun*, and the *infinitive*. Only the gerund and the participle are included in this discussion; any noticeable misuse of the other two forms in the books I have read is entirely negligible.

The *gerund* has an honored ancestry and a firm place in the language. In endless variety it is found in the best literature. Its misuse, however, in the technical and scientific writing examined for this paper has seemed excessive. Its legitimate use in certain of the books which I have read would have redeemed the language from a second-rate quality and made it unimpeachable.

The gerund is a verb-form ending in *ing*. Although it expresses action it makes no affirmation of a subject; yet the action must necessarily have reference to a definite subject, which must be expressed. Verb-form that it is, the gerund is invariably used as a noun. Example: "He acquired his aptitude in expression by *attending* to the subtleties of language." The gerund is distinguishable from the present participle, with which it is identified in form, by the fact that the participle has an adjectival function and invariably limits a noun or pronoun. Example: "*Attending* casually to the niceties of language, he unwittingly acquired an effective style of expression." In the following sentence the participle is substituted for the gerund with the result that the statement of the thought is illogical: "They did not take into account the possibility of the earth *being* a self-heating body." The thought establishes the word *being* as the object of the preposition *of*, and hence makes it a gerund. In the language of the

sentence, however, *being* is used as a participle to limit *earth*, which in turn is wrongly made to serve as the object of the preposition. In other words, *earth*, which ought to be reduced to an adjectival form to limit the gerund *being*, has been made the subject of the participle *being*. The adjective and the noun have been made to exchange functions, with the result that the writer, who evidently meant *the possibility of being*, has said *the possibility of the earth*. The sentence should read thus: They did not take into account the possibility of the earth's *being* a self-heating body.

If the gerund is preceded by a pronoun the mistake of reducing the gerund to a participle is never made. For instance, the following three sentences, which were written in consecutive order, reduce the gerund to a participle when it is preceded by a noun, but recognize its legitimate use when it is preceded by a pronoun: "There was trouble with the *hammer getting* off the handle." "But he hit upon an improvement which led to *his being* able to put a hammer upon a handle in such a way that it would stay there." "With this improvement,—there is no danger of the *head flying* off."

A popular misuse of the gerund is the omission of its subject: "On *sending* the spark from the induction coil through the tube the little wheel is driven round." The writter did not intend the reader to understand that the sending was done by the wheel, and yet the logic of the language distinctly says that it was. It is better in this sentence not to use the gerund, as there is nothing gained by introducing its subject. The statement might be phrased thus: When the spark is sent from the induction coil through the tube the little wheel is driven round. Or it can be phrased as follows: On the sending of the spark from the induction coil through the tube the little wheel is driven round.

The use of the *participle*, as well as of the gerund, without an expressed subject is very common: "Now *throwing* a beam of ultra-violet light upon the disk, the leaves are seen to collapse rapidly." The logic of the language, as a matter of fact, makes *leaves* the subject of the participle; but the writer

did not intend to say that leaves throw a beam of ultra-violet light. As there is no need of introducing the subject the participle should not be used. The sentence could be written thus: When we throw a beam of ultra-violet light upon the disk the leaves collapse. Or, if the participle is insisted upon its subject must be expressed: Now *throwing* a beam of ultra-violet light upon the disk, *we* cause the leaves to collapse.

Akin to the gerund and the participle which have no expressed subject to attach themselves to is the dangling elliptical clause. Although it has no part with verbals, nevertheless it is due to the neglect on the part of the writer to provide each term indicating action with an expressed subject: "*When utterly disheartened* I have encouraged the boy." Whether *I* or *the boy* is disheartened can not be determined without help from outside the sentence. The logic of the language makes *I* the subject of disheartened; the general presumption, however, would be in favor of *the boy* as the subject. In that case the thought might be expressed thus: When the boy has been utterly disheartened I have encouraged him. A subordinate clause should not be made elliptical unless its subject is the subject of the clause which it limits. The following use of the elliptical clause is entirely legitimate: *When entirely disheartened* he still put on a good front.

Reference.

Reference words skilfully used are clearly labor-saving devices in the language machine. Misused, they throw the machine out of gear. The pronoun, chief of the reference words, requires pretty careful handling. It refers specifically to a definite word; and any attempt to cover larger ground in its reference, or any use of it that admits two possible references, inevitably results in disjointure in the language. In case it can not have a specific word for its reference there is no call for its use. To introduce a pronoun, for instance, when the thought requires a conjunction is illogical: "Bolton asked Watt to act as his attorney, *which* he did." Substitute *and* for *which:* Bolton asked Watt to act as his attorney, *and*

he did. Again: "When the paint dried, *which* it soon did, he completed his toilet." When the paint dried, *as* it soon did, he completed his toilet.

It is illogical to introduce a pronoun as substitute for an antecedent which has not been expressed: "The wood ought never to be varnished, for *it* gives a common look to the article." Drop the pronoun and use the noun instead: The wood ought never to be varnished, for *varnish* gives a common look to the article.

The reference must be single, and not ambiguous: "Here the Rockies are not in the least like those crossed by the Union Pacific—so modest and uneventful you scarce know where *they* begin or leave off. You can put your foot on the very spot where *these* begin." *They* refers with impartiality to the Rockies in both places. *These* likewise. The ambiguity produces mental dizziness. But the general looseness with which the comparison is drawn between the two sharply contrasting situations accounts for the failure of the language to deliver its thought effectively and with precision. The problem here is not so much one of reference, however, as of parallelism. Here is the writer's opportunity to try out the devices of parallelism and balance, for accuracy of portrayal and for telling effect. The two parallel situations with opposite characteristics require parallelism in phraseology and a careful balancing of one item against the other: Here the Rockies are not in the least like those crossed by the Union Pacific: here you can put your foot on the very spot where they begin; on the Union Pacific they are so modest and uneventful you scarcely know where they begin or leave off.

Connectives.

The following is an illustration of the common misuse of reference words that seem to partake of the nature of both conjunctions and adverbs: "The dwellers in the intermediate region were better provided with vegetable food, *yet* they needed supplies of winter food." *Yet* is a kind of hybrid—a cross between a conjunction and an adverb. But its con-

junctional office is only a shadowy and unsubstantial one and in the grammar of the sentence is entirely lost. Its function is invariably that of an adverb. In the sentence above it is used apparently as a subordinate conjunction to introduce the clause *they needed supplies of winter food,* and to limit the verb *were provided.* An analysis of the sentence shows *yet* to depend upon the verb in the clause which it introduces; but an analysis of the thought discovers the subordinate part in the words *they were better provided with vegetable food.* The following sentence adequately expresses the thought: The dwellers in the intermediate region, although they were better provided with vegetable food, yet needed supplies of winter food. If *yet* were preceded by a semicolon all suspicion of its use as a subordinate connective would be at an end, and no other charge could be brought against it: The dwellers in the intermediate region were better provided with vegetable food; *yet* they needed supplies of winter food. Or the period would serve as well: The dwellers in the intermediate region were better provided with vegetable food. Yet, they needed supplies of winter food. Or the comma may be retained if the coördinate conjunction *and* is introduced to lift the conjunctional office from the shoulders of *yet:* The dwellers in the intermediate region were better provided with vegetable food, *and* yet they needed supplies of winter food. *Yet* is typical of a group of words whose use is identical and whose office is commonly misunderstood. They are: *so, therefore, then, hence, still, nevertheless, however, furthermore, moreover, accordingly, otherwise, also, besides,* and possibly one or two others.

In conclusion it might be of interest to state that the error most commonly met with in the reading of technical and scientific books is the misplaced *only.* Pride of workmanship joins with logic in demanding that *only* and her sister words receive accurate placement. Technical writers seem largely to meet this demand with indifference. The writer of the following sentence impaired his reputation for precision of statement, and momentarily confused his reader, by failing

to shift *only* to a position after *connected:* "There was a flat flooring, only connected by pins and bars with the closed side of the boat." The writer of the sentence has failed to realize what he has said: the statement betrays that the writer was not keenly alert to the virtue of clear thinking or of precise statement. The difficulty, of course, is that *only* may be attached to words, phrases, and clauses as well as to substantives, verbs, and adverbs. Like the infinitive, it becomes elusive in the variety of its applications. In the sentence, "The discussion of the most important point can *only* come up after the next chapter," *only* has been allowed to stray away from its principle, which is the phrase *after the next chapter,* and to have its relationship usurped by the verb *come.* The sentence as written means that the point can do nothing except come up after the next chapter. The intended meaning is that the point can come up after the next chapter, and at no other place. Although the illogical use of *only* borders closely upon the ridiculous, yet the use is common. In the logical use of *only,* however, the writer's habit of close thinking is first established: in it is the measure of his intellectual uprightness in his dealings with the English tongue.

There is possibly not so much of uncertainty on the part of the writer regarding the language devices treated in this discussion as of incomplete realization of what he has actually written. Although some of the devices are more or less elusive till one has "nailed" them, so to speak, yet one has only to look at them a second time to recognize their logical force and their title to respect. A modest submission to their behests is the sign manual of standard composition: ignoring them clogs the machinery of language; yielding them a respectful degree of conformity makes for power and efficiency in expression. To attend to the necessary revision of language contemplated in this discussion is to redeem from the category of flabby and ineffective writing a composition that may be sound in purport and valuable in content. The prevalence of illogical statements in works of otherwise high

merit suggests the rich return that careful revision may yield. The structural readjustments for language efficiency, such as are here exemplified, is the kind of thing for which the technical man is peculiarly fitted by virtue of the type of training he receives.

III. *Standards and the Student.*—In the matter of language expression the American student of technology is setting his standard too low to meet the requirements of his profession. No one knows better than the technical man himself, when he gets out into the stream of things, how exacting are those requirements, and how dearly he pays for his lack when he can not meet them. For instance the Alumni of Tau Beta Pi recently insisted to a man that the undergraduate engineer be provided with more and fuller instruction in English, as reported in *The Bent* for April, 1916. The technical student, especially during his first years in college, is likely to make inadequate preparation for the practical use of his language; and any special study of composition that may be urged upon him he is likely to resent. With this attitude toward the study of English perhaps it is not strange that he should regard his teacher of English as something of a visionary and pretty much out of sympathy with practical things. The lure of the practical and the immediate is strong upon him. His choice of a technical college implies that he is eager to be about the tasks of life and chooses to pursue only the so-called technical studies necessary to his profession. In this frame of mind he would regard a study of currency as useless to one who already knows the denominations in which it is issued; and for one who has long known the names of things language-training seems to him superfluous. At a time when there is so much active practice with instruments and materials to claim his attention it is not strange that he is likely to feel a little ashamed to be juggling, like a schoolboy, with the elements of speech. Movement, activity, and a large range in the laboratory and in the field are likely, from his present point of view, to outweigh in value any mental gymnastics that the study of language imposes. He has not yet

reached that point of vantage where the architect is seen as the peer of the builder, or the engineer with a sharp pencil as taking precedence over the engineer with a transit, or the man at the desk, who dictates the letters and the drawings and the specifications, as the one in command. In short, the student of technology is likely to overlook the importance, in his chosen field, of a mind trained to marshall ideas and give them apt and adequate expression.

The problem would seem, therefore, to be one of attitude and point of view. It would be so especially at the start. Efficiency in his work, success in his profession, or well-being in his life is conditioned on the education of his mind—of this the serious student of technology usually is convinced. Often, however, he is not aware that the education of his mind is conditioned upon his point of view. His point of view may be that of one who expects to be only a hireling, or possibly only a mechanic; or he may have the point of view of one who expects to be nothing less than a leader in his profession. He wishes, of course, to have credit—and to deserve it—for discrimination and good judgment. There is no high power of discrimination necessary to judge between sand and salt; but to discriminate between prejudices, presumptions, and personal conveniences on the one hand, and the big things of life on the other, is of tremendous importance. If the student takes the view that such discrimination is necessary, the education of his mind will take care of itself; otherwise his point of view will be his undoing. If in his writing and speaking, as in his figuring, he holds himself to the facts and to correctness of form and method, his point of view is sound and will result in a habit of clear thinking. Indeed, he is not safe until he is positively of the temper of mind to consign clumsiness, indefiniteness, and ambiguity of language to the discard of profanity, dishonesty, and soiled linen. Whether he is paid a debt, or pays it, he is to insist on its being paid adequately and not approximately. Whether he writes or reads he is to insist on accurate and adequate expression. As an engineer he would not accept in a finished

structure a mere approximation to his mechanical design; neither can he afford, as a builder of language structures, to be content with an ambiguous or an illogical expression of his thought design. A technician is nothing if not accurate and adequate not only in his structures but also in his drawings, reports, specifications, and contracts.

Even after he has acquired the temper of mind and the point of view, still he is encumbered with the handicap of inexperience. He who has not yet had experience with practical life is in a difficult position to acquire a standard that is practical. Without experience it is difficult for him to get a vivid impression of the practical lines upon which business generally proceeds, of the points that rule in the professions, and of the social forms that carry in the psychology of commerce. Without experience it is difficult for him to see that the echo he gets from the world is the reaction of his own personality, and that it is a positive, clean-cut, and definite personality that gets quick and strong and favorable response. Of course, the student cannot fully know without experiencing. But much may be done to help him to anticipate. He is to be encouraged in the idea that the ethics of his profession concern themselves largely with matters of appearance and language and conduct, and in a wholesome respect for conservation and balance, sanity and proportion, discriminative judgment, and the power to recognize what is fair and good. With the lure of the efficient mind will certainly come the revelation that mere conformity to the technical principles underlying his profession is by no means the sum of the observances he will be expected to make. And along with this wider range of concerns, he is to be especially encouraged in the idea that he can ill afford to ignore the need of perfecting himself in the use of the language.

REGULATIONS GOVERNING ENLISTMENT.

It became evident about the first of December that energetic measures must be taken by this Society to do everything it could to secure a ruling from the Provost General in regard to enlisting engineering students in the Enlisted Reserve Corps so that they might finish their course before entering active service. The following committee, consisting of G. C. Anthony, F. L. Bishop, S. P. Capen, Robert Fletcher, Hollis Godfrey, J. F. Hayford, Ira N. Hollis, C. S. Howe, D. C. Jackson, M. S. Ketchum, F. W. McNair, C. R. Mann, Mansfield Merriman, W. G. Raymond, C. Russ Richards, G. F. Swain, W. M. Thornton, and F. E. Turneaure, was appointed by President Ketchum and met in New York City on December 6 in connection with the annual meeting of the American Society of Mechanical Engineers and the Council of the Engineering Societies. As a result of this meeting, President Ketchum, Professor Swain and President Howe were appointed a committee to present resolutions which were drawn up and passed at this meeting, to the Secretary of War. They proceeded to Washington and discussed the subject at length with various officials of the War Department. The committee was fortunate enough to have the assistance of Dr. Mann who was called to Washington at this time. This committee has been made a permanent committee of the Society. As a result of the agitation in regard to the subject the following regulations have been issued:

WAR DEPARTMENT
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON

December 15, 1917.

REGULATIONS GOVERNING ENLISTMENT BY ENGINEERING STUDENTS IN THE ENGINEERING BRANCH OF THE ENLISTED RESERVE CORPS.

1. The Selective Service Regulations have recently been modified by inserting the following:

Under such regulations as the Chief of Engineers may prescribe, a proportion of the students, as named by the school faculty, pursuing an engineering course in one of the approved technical engineering schools listed in the War Department may enlist in the Enlisted Reserve Corps of the Engineer Department and thereafter, upon presentation by the registrant to his local board of a certificate of enlistment, such certificate shall be filed with the Questionnaire and the registrant shall be placed in Class V on the ground that he is in the military service of the United States.

2. In accordance with the authority given by this modification of Selective Service Regulation, the following regulations are promulgated governing the enlistment by engineer students in the Engineer Enlisted Reserve Corps.

3. In order to be eligible for enlistment in the Engineer Branch of the Enlisted Reserve Corps under the above-quoted amendment to Selective Service Regulations, a candidate must fulfill the following conditions:

(*a*) He must be a citizen of the United States.

(*b*) He must be a student in one of the schools, the names of which are borne upon the list of technical schools approved by the Secretary of War for the purpose of carrying out Section 5 of the River and Harbor Act approved February 27, 1911, relating to appointments from civil life to the grade of second lieutenant in the Corps of Engineers.

(*c*) He must be regularly enrolled and must be pursuing a course required for the degree of chemical engineer, civil engineer, electrical engineer, mechanical engineer, mining engineer or some other equivalent engineering or technical degree.

(*d*) He must have made, since his entry upon this course at the school, a record of standing which will indicate clearly that he may be regarded fairly as deserving a place among the first third, based primarily on the scholastic records, of the young men who have graduated from that institution during the past ten years.

4. Each candidate for enlistment must submit an application made out in his own hand and in the following form:

.....
(Place)

.....19..
(Date)

THE CHIEF OF ENGINEERS, U. S. ARMY,
WAR DEPARTMENT,
WASHINGTON, D. C.

Sir: I hereby apply for enlistment as a private in the Engineer Enlisted Reserve Corps of the United States Army. My full name is ..... I was born on
(full name without any abbreviations whatsoever)
..... at ..... I am a
(date of birth) (place of birth)
citizen of the United States by (birth / naturalization). I am a student at ..... and am in my ..... year and am
(name of institution)
pursuing a course in .....
(course which candidate is pursuing)
and am a candidate for the degree of.....
(degree for which candidate is working)
..... My home address is .....
(street) (city)
.....
(state)

Very respectfully,

(Signed) .....

(School address) .....

5. Each application must be accompanied by a certificate from the president or dean, *carrying the seal of the institution and made under oath* before a notary public or other civil officer authorized to administer oaths, in the following form:

I hereby certify that ..... is a
(full name of candidate)

regular student, in good standing, at .....
(name of institution)

and is pursuing the ..... year of
(1st, 2d, 3d or 4th year)

the course, in ....., and is
(course which candidate is pursuing)

a candidate for the degree of .....
(degree for which the candidate is working)

.....

I further certify that in the judgment of the faculty of this institution, as indicated by the academic records, supplemented by his relations with his fellow students and by observation of his instructors, he may be regarded fairly as deserving a place, qualitatively, in the first third of the young men who have graduated from this institution during the past ten years.

.....
(signature)

Sworn and subscribed to

before me, this ....

day of ....., 191... (office held at institution)

(Notary's seal) (Seal of Institution)

6. In order to receive prompt consideration, applications from candidates now at college, and who are over twenty-one years of age, should be submitted so as to reach the office of the Chief of Engineers in Washington not later than January 15. The application from a person who has not reached this age at the present time must be submitted within three months before, or one month after, he reaches the age of twenty-one.

7. As rapidly as possible after the receipt of the applications in the office of the Chief of Engineers, they will be carefully examined, and the candidates whose applications are approved will promptly be sent cards of authorization, authorizing them to be enlisted in the Engineer Enlisted Reserve Corps by an officer authorized to make enlistments in the Army, provided, of course, that they pass the necessary

physical examination which will be immediately prior to enlistment.

8. When thus enlisted the student's name will be placed on the "inactive list" of the Engineer Enlisted Reserve Corps, and he will be allowed to remain on this inactive list in order to enable him to complete his course at the institution.

9. Immediately after the completion of this course, or upon his discontinuance of the course for other reasons, the student will be given the option of being called into active service under his enlistment and being assigned to some one of the engineering branches of the Army, or of being immediately discharged and taking his place again among those subject to service under the draft.

W. M. BLACK,
Major-General, Chief of Engineers.

Approved:

NEWTON D. BAKER,
Secretary of War.

COMMUNICATION RELATING TO THE RECENTLY ISSUED REGULATIONS GOVERNING ENLISTMENT BY ENGINEERING STUDENTS IN THE ENGINEER BRANCH OF THE ENLISTED RESERVE CORPS.

TO THE HEADS OF ENGINEERING SCHOOLS:

The regulations permit high-grade work at an engineering school to be classified as a branch of the military service of the United States. The honor of enlistment in the Enlisted Reserve Corps of the Engineer Department is extended to all engineering students, who in the opinion of their faculties are reasonably certain to become successful engineers. The proportion of the students to whom this privilege is granted is not fixed but must be determined by each school on the basis of its experience and in accordance with its best judgment. Under these conditions it is expected that the schools will appreciate their opportunity and administer the regulations conscientiously.

To this end the undersigned committee of the Council of National Defense makes the following suggestions:

1. The "first third" mentioned in the certificate on page 3 of the regulations does not apply to any one class but to the graduates of the school by whom the standard is set. In a poor class it may happen that less than one third can be recommended for enlistment; in a good class, on the other hand, more than one third may be recommended. The entire responsibility of deciding which men are to be recommended rests with the faculty of the school. It is evident that this is a very elastic regulation. The committee, however, ventures to point out that it will not be advantageous to an institution to include among the candidates that it recommends the names of any men who probably cannot be admitted on account of physical disqualification or of any whose promise of usefulness as engineers is, in the judgment of the faculty, doubtful.

2. Schools are advised to require each candidate to take the physical examination given by the local board immediately and not to issue the certificate prescribed in paragraph 5 of the regulations until the candidate has passed the physical examination.

3. The provisions for eligibility for enlistment in the reserve corps prescribed in paragraph 3-C apply only to resident students.

4. Paragraph 3-C applies to students pursuing courses leading to the degree of B.S. in any of the engineering branches, as well as to those pursuing courses leading to the degrees mentioned and to those students in residence pursuing graduate courses leading to these and other higher engineering degrees.

5. Paragraph 5 of the regulations mentions three different things, all of which should be taken into account in selecting the students who may enroll in the enlisted reserve corps; namely their academic records, their relations with fellow students and the personal observations of their instructors. The War Department has adopted an effective method of rat-

ing candidates for officers' Training Camps on their personal qualifications. A copy of circular C. C. P. 201 explaining this method is enclosed.

6. The regulations state in paragraph 3-B that in order to be eligible for enlistment in the engineer branch of the Enlisted Reserve Corps a student must be enrolled in one of the schools "the names of which are borne upon the list of technical schools approved by the Secretary of War for the purpose of carrying out Section 5 of the River and Harbor Act, approved February 27, 1911, relating to appointment from civil life to the grade of second lieutenant in the corps of engineers." The list referred to is not to be published by the War Department. If the officers of an institution are uncertain as to whether the institution is included in this list, they are advised to inquire of the Chief of Engineers.

7. President Wilson and Secretary Baker have urged that it is the patriotic duty of all students in engineering colleges to stay in school if possible until actually called to the colors. The War Department recognizes that technically trained men are essential to all army operations and intends to detail drafted men who have taken engineering courses to the type of service for which their training best fits them. To this end students who may not be recommended for enlistment in the enlisted reserve corps but who remain in school until called to camp are authorized to file with their occupational census questionnaire at camp, a letter from the president of their school stating their special qualifications. The Secretary of War has assured the colleges that every effort will be made to use each student's special training in the specialized occupations of the army.

8. It will ensure prompter action on the certificates if each school will submit together with the certificates, a table showing the number of students in the freshman, sophomore, junior and senior classes who were pursuing regular engineering courses during each of the last two academic years: and the

number of graduates in engineering in each of the last two academic years; also a description of its marking system.

9. The War Department does not plan to issue any printed blanks for the certificates called for in the regulations—each school must supply its own in the standard form.

Respectfully submitted,

F. L. BISHOP, *Chairman*,
C. S. HOWE,
M. S. KETCHUM,
C. R. MANN,
S. P. CAPEN,
Committee on Engineering Education of the Council of National Defense.

EDITORIAL.

ENGINEERING STUDENTS ENTER THE MILITARY SERVICE WHILE IN SCHOOL.

It has been recognized from the very beginning of the war, not only by the Secretary of War but by other officials in Washington, that the successful outcome of the war for the Allies is dependent upon the service of technically trained men.

If the war is to last for a year or perhaps two, then we are all agreed that every student should do his part by dropping his school work temporarily, but if the war, as we believe, is to be of long duration, then it becomes absolutely necessary that technical students should be continued in school to complete their courses in order that a supply of such men may be available during the war and for the reconstruction period which is to follow.

This matter was taken up by Dr. Godfrey as a member of the Advisory Commission of the Council of National Defense early in August and referred to the Committee on Engineering Education of the Council. This committee coöperated with various other agents in bringing the matter directly to the attention of the officials in the War Department most interested in this matter.

Students taking special courses such as that for radio engineers under the direction of the Signal Corp of the U. S. Army are to enlist in the Engineer Enlisted Reserve Corp, and state in their applications that they prefer service with the Signal Corp.

The following letter was received from Dean A. A. Potter, of the Kansas State Agricultural College, and shows the enrollment in Land Grant Institutions.

The S. P. E. E. may be interested in an investigation which I recently made with reference to the effect of the war upon the engineering enrollment of Land Grant Institutions.

A circular letter was sent out to the deans of engineering divisions of land grant institutions. Replies were received

from thirty-three institutions with results as indicated below:

1. The enrollment in 1917–1918 as compared with 1916–1917 indicated an average decrease of 20.8 per cent. The losses for separate institutions varied from 4 per cent. to 42 per cent.

2. As compared with 1915–1916, the enrollment in 1917–1918 indicated an average loss of 20.1 per cent. The losses varied from 3.5 per cent. to 38.6 per cent.

3. Gains in enrollment at the beginning of the academic year 1917–1918 as compared with 1916–1917 were given by the Alabama Polytechnic Institute, the University of Florida, the New Hampshire State College, Rutgers College and the Texas A. & M. College.

4. As to geographical location, seven Institutions in the North Atlantic Group reported for 1917–1918 an average decrease of 20 per cent. as compared with 1916–1917. Five Institutions in the South Atlantic States show an average decrease of 12 per cent. The average loss for nine institutions in the North Central States is given as 23.2 per cent. The six institutions in the South Central States indicated an average loss of 18 per cent., while four institutions from the Western States showed an average decrease of 25 per cent.

5. The greatest loss seems to be in architecture, the average being 44 per cent. The average loss in electrical engineering is 28 per cent., in mechanical engineering 25 per cent., in civil engineering 23 per cent., and in chemical engineering 12.5 per cent. Four institutions reported gains in mechanical engineering, four in electrical engineering, eight in civil engineering, and nearly one half of the institutions teaching chemical engineering reported gains.

6. The losses for the various classes were approximately as follows:

	Per Cent.
Freshmen	1.5
Sophomores	14.2
Juniors	32
Seniors	31

BOOK REVIEWS.

Technic of Surveying Instruments and Methods—A manual of exercises in the use of surveying instruments and methods of surveying together with sample student surveys. By WALTER LORING WEBB, C.E., and JOHN C. L. FISH, C.E. First edition. New York, John Wiley & Sons. 319 pages. Cloth, 4 × 7.

The purpose of the author is not to replace any general textbook in surveying but to supplant the general directions in such a book by detailed directions for specific operations in the field and office. It is aimed to make these detailed directions so complete that the student can go through the routine of the exercises without verbal instruction, so that the instructor may be free to watch carefully the performance of each student, and give advice, explanation, suggestion, caution or illustration according to the needs of that student.

Each of the various surveying instruments are taken up in turn and graded exercises given designed to give the student a maximum amount of practice in manipulation and reading in a given time. The exercises are also in the nature of experiments in that the student has forcibly brought to his attention the sources and range of error in the operation performed. Following the exercises on manipulation are a series of exercises on surveying methods in which simple but practical exercises in differential and profile leveling, traverses, stadia work, curves, etc., are given.

In a separate section of the volume, complete descriptions and detailed directions for a complete student railroad survey (including the paper location and the final field location), a complete student topographic-hydrographic survey, and general directions regarding planning surveys are set forth, while the final section is made up of exercises in the use of the various office instruments and processes connected with the measuring of areas, plotting of maps and traverses, making of diagrams, constructing of scales, plotting of contours, etc.

The value of a book of this sort for use in connection with a course in surveying is beyond question; and the value of this particular book is further enhanced by the circumstance that it is the outcome of an extended experience both in the classroom and in actual practice. It is a book with a purpose, and that purpose has been admirably fulfilled.

L. W. McI.

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1906—Great Northern
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1911—Southern Pacific
1913—Butte, Anaconda & Pacific
1916—Chicago, Milwaukee & St. Paul
1917—Victorian Railways, Australia

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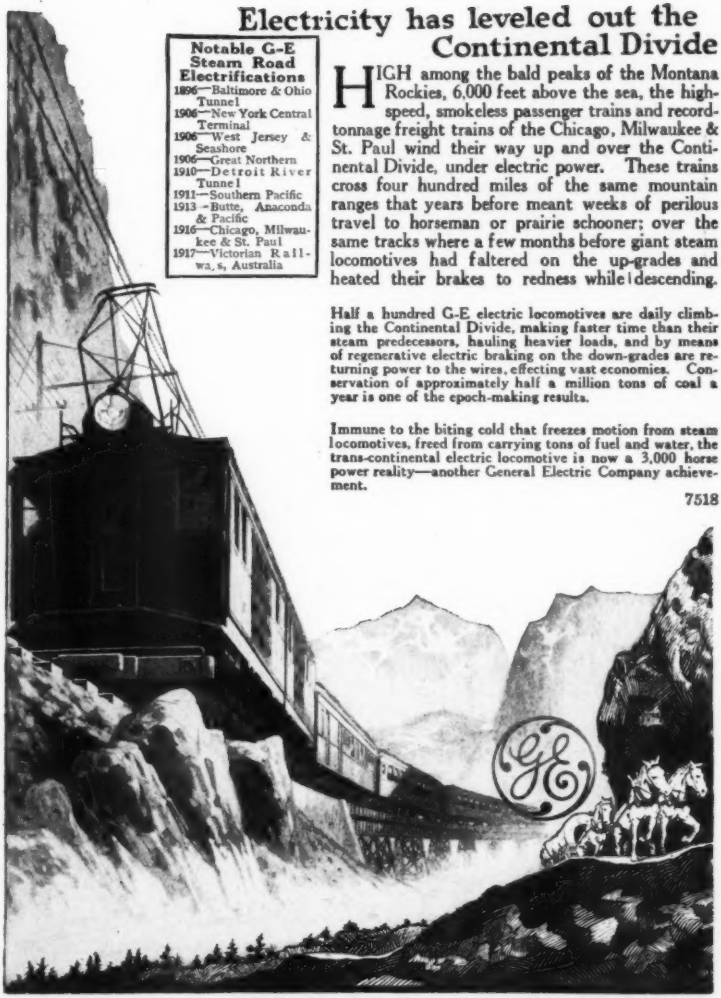

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Milo S. Ketchum, G. R. Chatburn, F. L. Bishop

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